The conservation status of the Spectacled Flying Fox *Pteropus conspicillatus* in Australia

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ABSTRACT

A survey of all known Spectacled Flying Fox camps in the wet tropics was undertaken in March 1998 with the assistance of volunteers. About 153 000 flying foxes were counted at 12 major camps. These data are compared with historical data and the status of the species in Australia is discussed. The imperative for conservation management of the Spectacled Flying Fox is emphasized regardless of its official conservation status, particularly in relation to seed dispersal and pollination of rainforest plants. The most important component of this management must be the development of non-lethal deterrence at orchards followed by the development of methods for countering tick paralysis. Further annual censuses will be necessary to monitor population trends in comparison with the current baseline. This initial census was conducted as part of an integrated approach to Spectacled Flying Fox management by fruit growers, researchers, conservation groups and the Queensland Parks and Wildlife Service.

Key words: Spectacled Flying Fox, *Pteropus conspicillatus*, Census, Conservation assessment, Rainforest.

INTRODUCTION

The Spectacled Flying Fox *Pteropus conspicillatus* occurs in northeastern Queensland, New Guinea and nearby islands (Koopman 1982; Hall 1987). In Australia it is restricted to the east coast of Queensland north of Cardwell, with extralimital records from Brisbane and Chillagoe (Hall and Richards 1979; Richards 1990a). Unlike other large flying foxes from mainland Australia, the Black *P. alecto*, Grey-headed *P. poliocephalus* and Little Red Flying Foxes *P. scapulatus*, the Spectacled Flying Fox is associated primarily with rainforest (Richards 1990a) in which it specializes on fruit (Richards 1990b, 1995).

Like other Pteropodids the world over, the Spectacled Flying Fox eats fruit in orchards causing substantial economic damage (Jamieson 1988; Tidemann *et al.* 1997). As a result many are killed by farmers attempting to protect their livelihood. In recent years there has also been considerable mortality from tick paralysis (Spencer *et al.* 1992; Eggert 1994; Johnson 1994). In addition, over the last century, a significant proportion of the species' habitat in the wet tropics bio-geographical region has been cleared for agriculture and development, especially in the lowlands, and there has been regular persecution of daytime camps. Nevertheless the species was still considered common in 1990 (Richards 1991a) and not threatened in its range as a whole (Richards in Mickleburgh *et al.* 1992).

In the light of these threats and observations that the species is declining (Richards 1990c; Werren 1993), it has been suggested that the Spectacled Flying Fox be classified as Vulnerable in Australia. This suggested status, however, was challenged by tropical Queensland fruit growers (A. Leu, pers. comm.; A. Yardley, pers. comm.) who feared a change in status, especially at the State level where conservation status has legal implications under the *Nature Conservation Act 1992* and *Regulations 1994*, would severely restrict their abilities to protect fruit crops with current technology. As a result of their representations to the Queensland Government, the Queensland Department of Environment was charged with initiating conservation management of the Spectacled Flying Fox. To obtain advice on the best way forward, a consultative committee was formed consisting of bat researchers, bat carers, fruit growers, a representative of a local conservation group and a veterinarian. The committee identified, as a first priority, a review of all information pertaining to the Spectacled Flying Fox and a census of camps in the wet tropics. From this it was hoped that a definitive determination of status would be obtained. The results of the review and census are presented in this paper along with proposals for conservation management.

METHODS AND STUDY AREA

Census

Estimates of camp size

A census of Spectacled Flying Foxes was conducted primarily by counting the number of bats leaving camps at dusk, using

hand counters (Parry-Jones and Martin 1987). After an initial reconnaissance of camps, presentations were made to volunteers to describe the biology of bats and techniques for counting. A group of volunteers was organized for each camp under a co-ordinator, with the aim of ensuring each camp was surrounded but that no stream of bats was double-counted. Counters assembled at camps before the evening fly-out and stopped counting when no further animals were seen leaving the colony or it became too dark to observe them. Bats were tallied in groups of up to 50 as they crossed a fixed point, usually a road verge or a powerline.

Flyouts were counted for all known camps between Daintree in the north, the Russell River in the south and the Atherton Tableland to the west. A total of 12 major camps was counted. Wherever possible, counts were made on three consecutive nights between 18 and 22 March, 1998. Timing was determined partly by an imperative to determine status and partly in an attempt to obtain a measure of peak numbers — in mid March most young bats can fly but breeding camps have not yet dispersed. In addition, counts were made during the daytime at camps at Bloomfield and Rossville, both north of the Daintree River, and Green Island and Banana Island in the week preceding the census. A small number of counts made earlier in 1998 were also documented for comparison with the simultaneous counts.

Searches of additional areas

Attempts were made to find camps in areas where Spectacled Flying Foxes had been reported but where precise camp localities were unknown. Searches were conducted along the Annan and Endeavour Rivers in the north and near the Brook Islands, Mission Beach area and near Tully in the south. An inspection was also made of the Cardwell and Ingham areas in search of Spectacled Flying Foxes.

Historical data

Data on the past abundance of Spectacled Flying Foxes were gleaned from all written material mentioning the Spectacled Flying Fox that could be obtained, including some unpublished reports, letters and government documents. Secondly anecdotal data were collected whenever possible. Collection of anecdotal data was not comprehensive and might best be described as indicative.

RESULTS

Census

Estimates of camp size and sources of error

The results of the Census are presented in Table 1. All known camps are shown on Figure 1 and described in Appendix 1. Counts at 12 major camps are a conservative total of about 153 000 Spectacled Flying Foxes. Three camps, believed to contain fewer than 500 flying foxes, for which counts were inadequate were omitted from the census results.

At some camps there was substantial variation between nights in the counts recorded. At camps where this variability was attributed to factors such as changed weather conditions, double counting or a shortage of

Table 1. Flyout numbers from Spectacled Flying Fox camps in the wet tropics of north-east Queensland, March 1998.

Site	Date of Count (March 1998)					Best Estimate	Estimated Error	Observers/ night
	19th	20th	21st	22nd	23rd			
Mossman-Cooktown								
Newell Beach			5 040			5 000	500	4
Daintree		27 230 (+5 000)		5 000 (+27 230)		30 000	2 500	4
Bloomfield	6 000					6 000	1 000	2
Rossville	4 400					4 000	1 000	2
Mulgrave River-Wonga Beach								
Cairns	58 750–81 750		24 500		21 500	40 000	20 000	8
Atherton Tableland								
Powley Road	6 460	9 420				9 000	500	6
Tolga	5 075	6 220	7 010			7 000	500	6
Whiteing Road	16 850	18 714	15 853			19 000	1 000	5
Topaz	1 503	2 850	5 553			6 000	500	4
Kuranda	20 000	11 420	8 923			10 000	1 500	5
Mulgrave River-Innisfail								
Fishery Falls	3 390		4 460			3 000	500	4
Russell River	14 520	14 250				14 000	1 000	4
Total						153 000	30 500	54

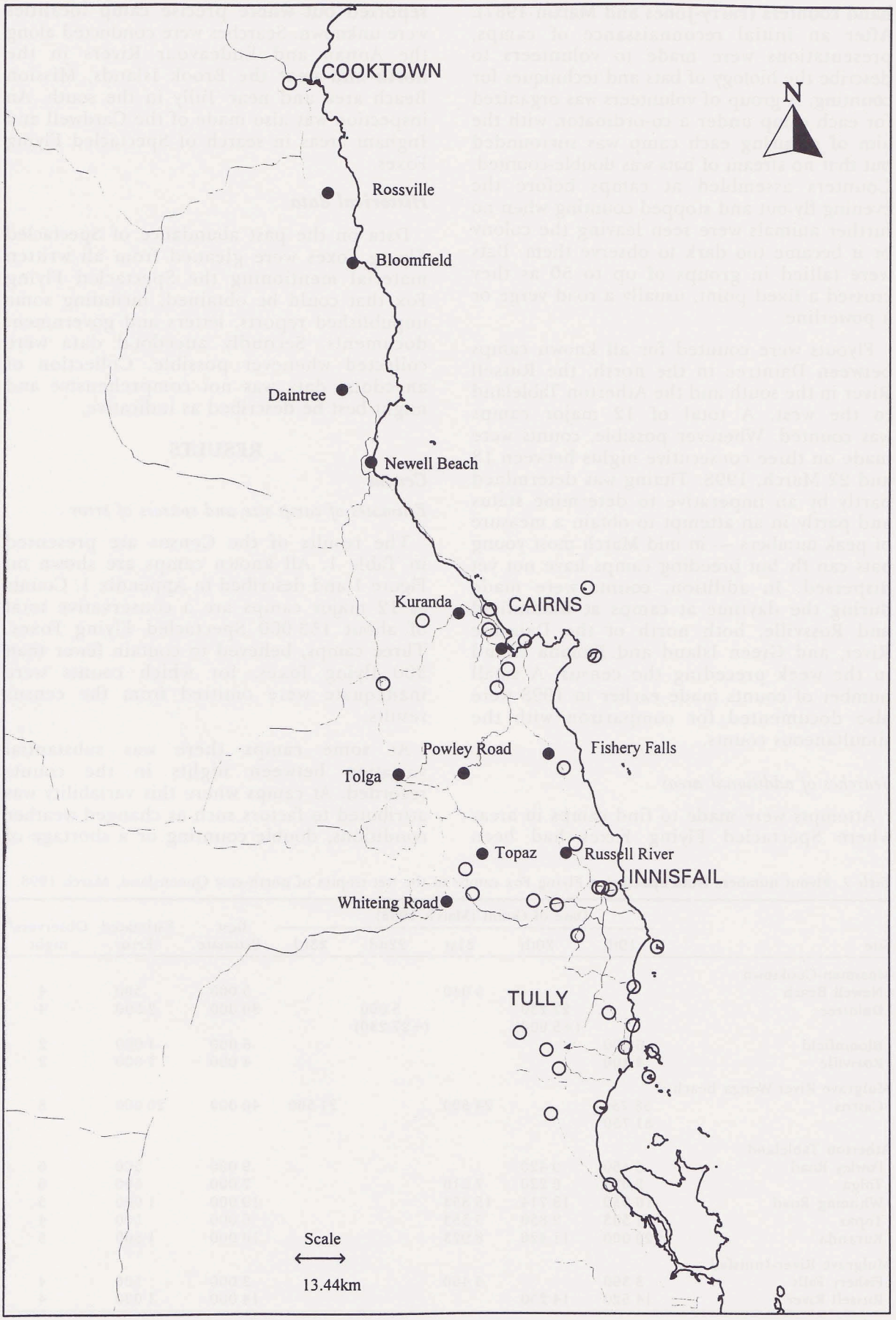

Figure 1. Locations of Spectacled Flying Fox camps in north-east Queensland, Australia. ● Camp occupied and counted during census (see Table 1). ○ Other camp sites (see Appendix 1).

counters, the co-ordinators nominated one count as that in which they had greatest faith in the numbers recorded. The best estimate was not necessarily the highest or lowest count. On the first night at Kuranda and the last night at Fishery Falls there was double counting; at Powley Road, Tolga, Whiteing Road, Topaz and Fishery Falls the earliest counts were in poor weather or missed flyout streams that were counted comprehensively on subsequent evenings.

At Russell River and the second and third nights at Kuranda any error was thought to be in the counting rather than the thoroughness of coverage so the numbers were averaged. Similarly the counts for Cairns were also averaged for the first and last nights, despite the wide variation. On the first night the higher figure is almost certainly the result of double counting, the second night there were too few counters and, on the third, one flyout path is known to have been missed and at least some bats remained in camp, possibly because of wet weather. Also flyouts at Daintree had to be counted separately because the colony was too large to surround in a single night. On 20th March, 1998 about 27 000 were seen flying in one set of directions. On 22nd March, 1998 a further 5 000 were seen flying in a different direction. There is a possibility that these separate night flyouts may have caused double counting or missed some bats because the numbers travelling each direction each night at other colonies varied considerably. To allow for this, the minimum and maximum possible for the Daintree have been averaged. An estimate of the error as well as a measure of average observer effort is also provided in Table 1.

Three earlier counts of camps in 1998 were also recorded. In Cairns a count on 12th February, 1998, when many juveniles remained in the camp at night, totalled 52 200. At Daintree, the population in the camp on 4th January, 1998 was 6 000 and 19th January 1998 it was 12 500.

Searches of additional areas

In addition to the above counts, searches of the Annan and Endeavour Rivers in the north failed to find any flying foxes. On Green Island the resort staff reported 27 while on Banana Island there were fewer than 100. At Cowley Beach, on an evening of poor visibility, fewer than 100 were seen flying ashore from the Brook Islands although they were known to be visiting orchards in the region. No camps could be located in the area between Innisfail and Hinchinbrook Island before the census but we subsequently learnt of three, none of which could be counted adequately.

Historical data

Mossman-Cooktown

The species was collected near Cooktown last century (Andersen 1912). Richards (1990a) marks ten camps, including one on the Windsor Tableland. There are no records of abundance. There have been no recent records of a camp on Windsor Tableland (C. Clague, pers. comm.) but there are reports of camps on the Endeavour and Annan Rivers (H. Spencer, pers. obs.), neither of which were present or could be found during the present count. The camps at Newell Beach and Daintree are permanent and have been present for many years, although the latter disappeared for some time in 1992 after Little Red Flying Foxes arrived in the same area (H. Spencer, pers. obs.).

Cairns (Wonga Beach to Mulgrave River)

Spectacled Flying Foxes are present in the Cairns district throughout the year (Richards 1990a). The type specimen was collected from Fitzroy Island in 1849 where there were "prodigious numbers" (Gould 1850). Small numbers still occasionally occur on the island.

The next known record is from 4th July, 1929 when Francis Ratcliffe wrote in a letter to his family (National Library MS 2493):

> "The northern districts are very hard to 'work' properly, the country is so wild and the information so hard to come by. But for the mango season, when the foxes are here in countless millions, the beasts seem to lead a nomadic life in search of food. Their camps are small and continually shifting. So far I have managed to come on one in the Cairns area."

Ratcliffe probably did not himself see "millions", having arrived in Cairns for the first time only a few days earlier. Later he wrote that "I met *conspicillatus* less than half a dozen times, though I chased it for months." (Ratcliffe 1937).

In the early 1980s there were flying fox camps on Admiralty Island (a mangrove islet in Trinity Inlet), at Edmonton, in Cairns Central Swamp and on the Barron River (Richards 1990a; C. Clague, pers. comm.). Richards describes 5 000 flying foxes leaving Cairns Central Swamp at the approach of a cyclone but otherwise there are no details on numbers, although there were many more in Cairns at the time (M. Trenerry, pers. comm.). The camps at Admiralty Island and Barron River were dispersed with high mortality. The former is occasionally used by small numbers, the others have been

abandoned. At the time of the count there were flying foxes only in Cairns Central Swamp and a small number on Green Island.

Atherton Tableland

Most camps on the Atherton Tableland are occupied only during the wet season, the animals leaving during the cooler months from April-June until August or September (Ratcliffe 1931, 1932; Richards 1990a). Ratcliffe visited the Atherton Tableland in July 1929, when he saw only empty camps, and November 1930 when, according to his letter of 12th November, 1930, he found two more camps, though gave no details of size.

His general account of camps on the Atherton Tableland suggest that there could have been great numbers: "Here, in a rather limited area, five camps were located (three of which were visited) separated from one another by about 15 miles. Four of them are annually inhabited and two at least are large [>50 000]" (Ratcliffe 1931, 1932). However, it is unclear whether he is discussing *P. conspicillatus* or *P. scapulatus* which elsewhere he says must visit the Tableland in "large numbers", describing a visit to one camp "on the Atherton Tableland in which a hoard of migrating *scapulatus* had camped". Elsewhere he says that "When a well known camp of one or other of [the large Flying Fox] species has been reported to attain unusual size, enquires often discovered the fact that *P. scapulatus* was present as well." (Ratcliffe 1932).

In 1947 specimens were taken from camps at Devil Devil Creek, Julatten and on the Clohesy River at Koah. Both were described as containing several hundred flying foxes (Tate 1952). In addition to these, Richards (1990a) lists four summer camps on the Tablelands (Millaa Millaa 1 and 2, Severin Creek and Peterson's Creek), three winter camps (Wongabel, Picnic Crossing and Mareeba) and two staging camps used between seasons at Beatrice River and Tolga Scrub. The Peterson's Creek camp contained 200–300 animals from October 1982 to February 1983. Of these camps Clohesy River is still used in the winter but Mareeba and Wongabel both appear to have been abandoned, the latter in 1997 after many years' occupancy, the former several years ago.

More recently the population at Powley Road was estimated in November 1992 to be 10 000–12 000 (Hayden 1992). Four months later, at the end of the breeding season when bats were starting to leave the camp, numbers declined from 13 000 on 16th March to 10 070 on 2nd April to 5 230 on 20th April, 1993 (Bull 1993).

At Zillie Falls, possibly the camp at Millaa Millaa visited by Ratcliffe, the population was estimated to be 8 000 in 1994 (Johnson 1994). The combined camps of Whiteing Road and Zillie Falls was estimated to have gone from 60 000 to 30 000 from 1996 to 1997. This was based on rough estimates by bat rescue volunteers retrieving paralysed bats in 1996 and 1997.

Mulgrave River — Innisfail

Near Innisfail there has, for a long time, been a camp in the nearby swamp. In 1961 (Harrison 1961) the species was the "common flying fox of the area. A fairly large colony ("camp") of some thousands occupied the swamp to the immediate east of Innisfail from January to May of both 1959 and 1960, while small camps are to be found scattered throughout the district at all times." In August 1964 there were 500–1 000 present (McKean and Price 1967). From 1981 to 1986 the pattern of occupation appeared to have changed so that two camps near Innisfail were occupied all year round while one was occupied only during winter (Richards 1990a). Of camp sites near Innisfail that have been used in recent years, Banana Island, Warrina Lakes and Innisfail Dump, only the first had a small number of bats at the time of our count. Similarly a camp at Eubenangee Swamp was empty but the nearby camp at Russell River had not been recorded before. Other camps abandoned in the last five years were at Deeral, near the existing Fishery Falls camp, and along Brooks Road, Millaa Millaa, possibly the Beatrice River camp recorded by Richards (1990a). One other camp at East Palmerston, was deserted after persecution around 1992.

Innisfail-Cardwell

Ten camps in this region have been marked on the map of Richards (Fig. 1, 1990a). These included two camps at Tully that were permanently occupied for many years, a camp at Mena Creek and a substantial seasonal camp in mangroves immediately south of Cardwell (D. Storch, pers. comm.). The mangroves at Cardwell were cleared in the late 1980s, the camps at Tully abandoned because of disturbance and that at Paronella Park, Mena Creek was abandoned because of persecution. There appears to be no documentation of the size of camps south of Innisfail except that Lavery and Grimes (1974) reported it as being "Abundant in closed forest south of Tully River". At the time of the count small camps were present at Scoogal Road near Tully, South Maria Creek and Kurrimine Beach but absent from known

locations at El Arish and at three sites near Mission Beach. Reports of small camps at Dunk and Bedarra Islands, at the mouth of the Murray River and at Bilyana Road could not be checked.

Northern population

On Cape York Peninsula the species occurs in the McIlwraith Range and Iron Ranges (Tate 1952; Winter and Atherton 1980; MacFarlane and Stager 1988; Richards 1990a) but has not been recorded from rainforest blocks further north on Cape York Peninsula or in riparian rainforest to the west. In Torres Strait a specimen was collected last century from Nepean Island (Andersen 1912) but there are no recent records. Judging from the failure of Thomson to secure a specimen in the late 1920s (Dixon and Huxley 1985), it has never been abundant. Richards (1990a) marks five camps for the region but none have been found recently and nor were any found by Tate (1952) or Winter and Atherton (1980). As at least part of the population camps within the forest in small groups (C. Blackman, pers. comm.), the behaviour of this population may differ from that in the wet tropics and make population estimation exceptionally difficult.

DISCUSSION

Census

The census has provided the first gross estimate of the Spectacled Flying Fox population in the central part of the wet tropics. Having said that, it was a census organized in haste and the total count is undeniably a crude estimate of only part of the population. The count was particularly crude for the largest camp, in Cairns, where a comprehensive census was hampered by heavy rain. Given this level of error the total counted population could have been as low as 120 000 or as high as 180 000. Also at least three camps at the southern extremity of the range were not counted adequately, and the Spectacled Flying Foxes at the Iron and McIlwraith Ranges were not counted at all. The total population immediately after the breeding season may thus reach 200 000. Nevertheless, although the error levels are substantial, they do provide a basis for later comparisons, particularly if there are dramatic changes in the population size.

To use these census figures to determine conservation status it is also necessary to discuss the life history parameters of the Spectacled Flying Fox, including new causes of mortality and potential rates of increase.

New and non-natural causes of mortality

The factors which have controlled flying-fox numbers in the past — whether predation, shortage of food or catastrophes — have never been quantified. However, since Europeans arrived in north Queensland, and especially in the last 20 years, flying foxes have been subject to a number of novel sources of mortality. These are discussed below with some attempt to estimate the likely effects on the population. It is acknowledged, however, that the effects of any new source of mortality could be overwhelmed by the effects on population size of natural though exceptional shortages of food.

Loss of habitat

While known to rely on rainforest, with all camps being within 6 km of extant forest, the exact habitat requirements of the Spectacled Flying Fox are unknown (Richards 1990b). In the wet season it is evidently capable of finding food in both coastal and upland rainforest. In the cooler months, however, those parts of the Atherton Tablelands subject to moist weather are deserted in favour of the coast or the drier western fringe (Richards 1990a). Spectacled Flying Foxes also make extensive use of woodland species, particularly *Melaleuca* spp., when in flower so that woodland near rainforest may be as important as rainforest itself.

Up until the 1960s the Atherton Tableland had lost 23.4% of its original rainforest (Winter *et al.* 1987). Since the 1960s the rate of clearing has slowed but between 1978 and 1988 alone an additional 1 400 ha was cleared on the Atherton and Evelyn Tablelands, about 10% of that remaining on freehold or leasehold land (Collins 1994). The pattern of clearing for the lowlands is shown in Figure 2. Up to 1975 about 46% of all vegetation in the lowlands between Bloomfield and Ingham had been cleared. By 1983 the proportion cleared exceeded 50% (Winter *et al.* 1987) and over the last 15 years it has reached about 80% (S. Goosem, pers. comm.). Even though only about 40% of this vegetation was rainforest (Winter *et al.* 1987), Spectacled Flying Foxes also feed in the *Melaleuca* woodland that was the other major vegetation type. Thus clearing is likely to have reduced substantially the carrying capacity of the region for flying foxes. Although the rate of clearing has now slowed, there being little unreserved arable land remaining uncleared, clearing is continuing on private lands.

To an unknown extent, the planting of exotic fruits may compensate for the loss of natural habitat, particularly in years when

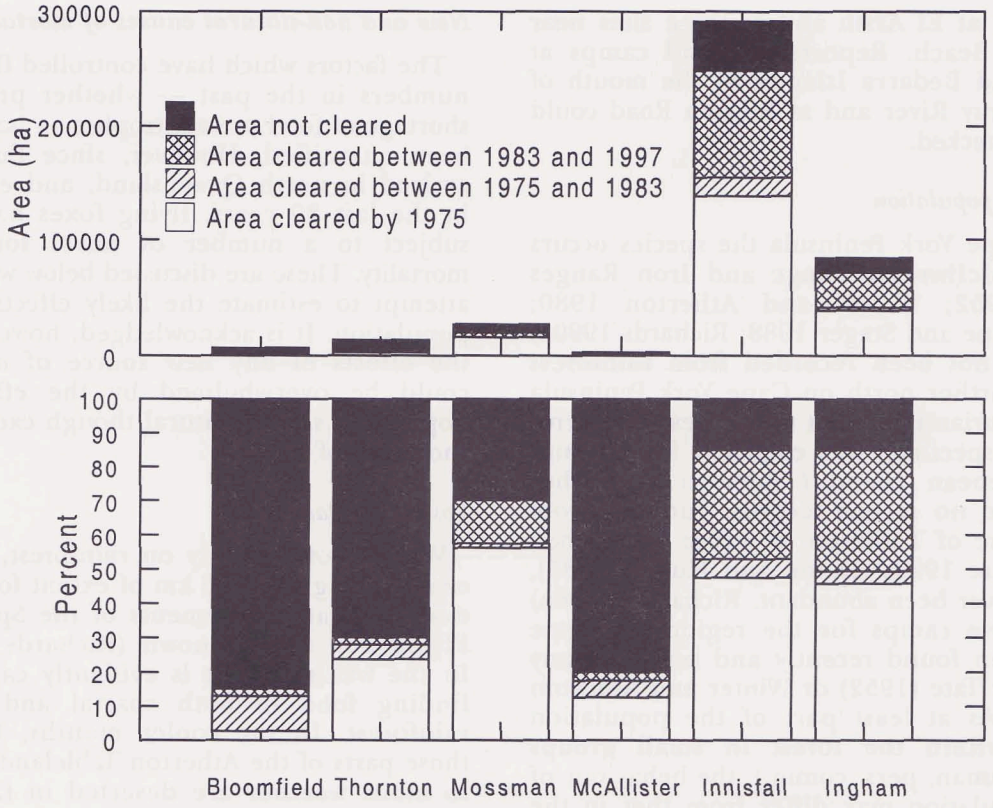

Figure 2. Distribution of vegetation below 80 m in the wet tropics showing the pattern of clearing since 1975. Regions are 1:100 000 map sheets. (Data for 1975 and 1983 from Winter *et al.* 1991; data for 1997 S. Goosem, pers. comm.)

natural fruiting or flowering is poor, but this also exposes the flying foxes to other threatening processes. Habitat clearance north of the Daintree River and in the extensive rainforest in the McIlwraith and Iron Ranges is minimal and is unlikely to have significantly affected the flying foxes in these areas.

Control at orchards

There has been conflict between flying foxes and fruit growers for as long as Europeans have been growing fruit trees in Australia (Tidemann *et al.* 1997). Although numerous techniques have been devised for keeping flying foxes away from orchards (Hall and Richards 1987; Fleming and Robinson 1987; Leu 1993, 1994; Turner 1994), there remains an urgent need to develop an effective and reliable system of non-lethal bat deterrence (Tidemann *et al.* 1997). In many ways, as Nelson (1987) pointed out over a decade ago, we are no better able to deter flying foxes today than we were in Ratcliffe's time in the 1930s.

The two most common methods of control are shooting and electrocution (McHold and Spencer 1998). Since 1994, when protection of the Spectacled Flying Fox resumed after a 10 year period during which there was no legal restraint on their destruction, both methods have required a permit for their use. Consequently there are some data on mortality from these sources. In 1997 a total of 1 202 flying foxes were shot under permit by 12 farmers. Little reliability can be put on these figures. Farmers rarely admit to shooting more than they are allowed while those who shoot fewer sometimes say they have shot more to ensure they get a permit for the same number the following year. Figures from earlier years are not available but were probably substantial, even though shooting takes exceptional diligence, accuracy and sleeplessness to be effective (J. Anderson, pers. comm.).

The second method commonly used is a lethally charged grid of electric wires, commonly called a "fyre-fox" (Anon. 1983). Permits for 10 such grids have been granted within the range of the Spectacled Flying Fox and from seven returns there has been a total of 856 flying foxes killed (range 36–336). This is certainly an underestimate. Alhough it is said that few bats are killed if the grid is turned on as a crop is just ripening, the mortality is said to be far greater if the flying foxes have been visiting a crop regularly (McHold and Spencer 1998). There is also an anonymous anecdotal report of one farmer

who switched on his new grid in the middle of the night. Large numbers of flying foxes were already feeding in the orchard and it is alleged that over 500 were killed. They were not declared on permit returns. In addition, a number of grids are thought to be operating without permits.

Ticks

Paralysis ticks *Ixodes holocyclus*, primarily a parasite of marsupials (Roberts 1952), were first recorded affecting Spectacled Flying Fox in 1988 (N. Goudberg, pers. comm.), and apparently were not doing so before 1986 (Eggert 1994; G. Richards, pers. comm.). The flying foxes show little resistance to the toxin, and single ticks are capable of causing paralysis, even when barely distended. Paralysed animals fall to the ground where they are prone to fly strike (Spencer *et al.* 1992) and predation by dingoes, pythons and Pied Currawongs *Strepera graculina*. A high percentage will respond to treatment with antivenin administered by dedicated carers (Johnson 1994) and at least some immature bats are known to survive to maturity after release (Williamson 1995). During 1994, 1 000 adult flying foxes were affected in the maternity camp at Zillie Falls (Johnson 1994). In 1995 at least 40 bats were collected from Tolga maternity camp (Maclean 1995) and 226 from the Whiteing Road maternity camp (Anon. 1995). Tick mortalities are considered a minor problem at Kuranda, Powley Road and Topaz and have been recorded at a low level of incidence at the lowland camps (C. Clague, pers. comm.). The epidemic in tick paralysis coincides with a switch in diet to wild tobacco *Solanum mauritianum* (Spencer *et al.* 1992; Eggert 1994). However, it is not known whether the bats are exposed to the ticks from the tobacco, which seems to harbour few ticks (Brice 1998), or are picked up by other means.

Disturbance of camps

Numerous attempts have been made to reduce the number of bats by persecution at their camps. Apart from direct mortality through shooting (e.g., Pierson 1984), disturbance of maternity camps during the breeding season is thought to result in the death of most dependent juveniles. Of the 15 camps recorded by Richards (1990a), three were at least temporarily dispersed by shooting. In recent years camps at Admiralty Island, Barron River, Edmonton, Banana Island and Paronella Park appear to have been abandoned altogether as a result of shooting; one camp at Syndicate Rd, Tully was abandoned after being smoked out; the camp at East Palmerston was poisoned and the camp at Oyster Point, Cardwell was cleared. The fate of bats after disturbance is unclear. It is not known how commonly suitable camp sites for Spectacled Flying Fox occur in the landscape. In the Northern Territory the availability of suitable camp sites is thought to be the main factor influencing the distribution and colony size of the Black Flying Fox (Loughland 1998).

Cyclones

Cyclones occur in most years within the range of the Spectacled Flying Fox. They are a problem for flying foxes because they strip fruit from the trees over substantial areas. Cyclones can be particularly devastating for island populations because such a large percentage of available habitat can be affected (Pierson *et al.* 1996). Observations in the Innisfail area after the particularly destructive Cyclone Winifred crossed the coast in 1986 suggest that flying foxes are able to both weather the storm and find food afterwards (Richards 1990a), possibly by foraging beyond the impact zone (M. Trenerry, pers. comm.).

Hunting

Unlike in the Northern Territory (Tidemann and Vardon 1997) and in the Pacific and Indian Oceans (Mickleburgh *et al.* 1992), hunting for food is an insignificant cause of mortality. Even at Iron Range the Spectacled Flying Fox are generally considered too sparse and in too poor condition to be worth hunting for food (C. Clague, pers. comm.). When unprotected they were also hunted for recreation in the wet tropics region and some shooting for entertainment may still occur illegally.

Competition

Competition from the Black Flying Fox for nectar, particularly in woodland trees, may be occurring in the southern part of the range of the Spectacled Flying Fox; and the Little Red Flying Fox sometimes displaces it from camps at Whiting Road, Tolga, Cairns Central Swamp and Daintree (Ratcliffe 1931; Richards 1980a, pers. obs.; H. Spencer 1992, pers. obs). However, as Richards (1990a) also found, the Spectacled Flying Fox was the only species of flying fox present at camps examined during the census and disruption by Little Red Flying Fox is usually only temporary.

Powerlines

Collisions with powerlines, barbed wire and traffic deaths are all recently recorded causes of mortality. The number of bats which die

in this manner is unknown. When bats short-circuit electricity wires they usually do not disturb supply, so the electricity authority has no records. As a higher proportion of flying foxes become resident in urban areas, the importance of deaths from this cause is increasing.

Life history

Spectacled Flying Fox gives birth to one pup annually. Females are capable of breeding at one year of age but, in captivity, few of these young survive. Males probably do not breed for three or four years. Males are probably polygamous, as they are in the Grey-headed Flying Foxes (Nelson 1989), and there is a ratio of at least 2:1 in favour of females in Spectacled Flying Foxes (C. Tidemann, pers. comm.). The number of live young in a maternity colony per female can exceed 90% (e.g., Bull 1993). Given the sex ratio of the maternity colony studied and this high apparent fecundity, breeding flying fox populations have a potential rate of increase of 1.3 (50% females successful) to 1.5 (80% successful). The natural lifespan is unknown. Although one captive animal reached 17 years (Hall in Flannery 1995), it is assumed most wild flying foxes live much shorter lives. For the purposes of analysis of the IUCN criteria, the generation time, which is the average age of the adult population (IUCN 1994), is assumed to be four years.

Conservation status

Status was assessed against IUCN criteria as these give the most objective categories. Of the five broad IUCN criteria on which a species can be judged as Endangered or Vulnerable, those relating to declines in area of occupancy or extent of occurrence (B), or small populations (C, D) do not apply. Furthermore too little is known about the life history of the Spectacled Flying fox to be able to produce the credible models required under E, especially measures of the degree of mixing between populations that are required under most population viability assessments.

Therefore the status must be determined on the basis of population trends (A). To be listed as Endangered, a species must have undergone an observed, estimated, inferred or suspected decline of at least 50% and to be listed as Vulnerable a population must have declined by 20% over the last 10 years or three generations, whichever is longer. The assessment of population trends can be based on any of the following: (a) direct observation, (b) an appropriate index of abundance, (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat, (d) actual or potential levels of exploitation or (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites or a suspicion that such a decline would take place in the next 10 years or three generations (IUCN 1994). For the Spectacled Flying the generation time (four years) and the relevant time period over which the change must have or be going to take place is 12 years. The five categories are discussed separately:

(a) Direct observation requires historical data on numbers. Ratcliffe's data on numbers are equivocal. His reference to "millions" in the mango season is not first hand and is probably the subjective observation of those whose mangoes were eaten. However, from many anecdotal accounts, there are far fewer flying foxes in Cairns than there were 20 years ago (M. Trenerry, pers. comm.)

On the Atherton Tablelands the writings of Ratcliffe could be interpreted to mean that he found four camps of greater than 50 000 animals, which is far greater than has been recorded recently. If there were 200 000 Spectacled Flying Fox on the Atherton Tableland in 1930, a decline of 20% every 12 years since would leave between 57 000 and 64 000 remaining, depending on whether the calculation is made in 12 year sections or annually. This census recorded about 41 000. On the other hand Ratcliffe only saw two camps he estimated to be "large" and at least one of these was probably dominated by Little Red Flying Foxes. If fewer bats now occur on the Atherton Tablelands, it is unclear whether this is typical of the population as a whole, given this population has suffered the greatest percentage decline in vegetation cover and is the worst affected by ticks. There is anecdotal information that there has been a major decline south of Innisfail and in Cairns but there is no suggestion of substantial declines north of Cairns.

(b) The only possible surrogate measure of abundance would be the number of camps but this is compounded by the bats' mobility. For instance it is known that Spectacled Flying Foxes no longer use Admiralty Island as a major camp since heavy culling. However, during the time Admiralty Island was in use in the early 1980s, the camp in Cairns Central Swamp was recorded as containing only 5 000 bats (Richards 1990a) whereas, on the first night of the census, there were estimated to be at least 59 000. Similarly the recent disappearance of the camp at Warrina

Lakes, Innisfail, which had been continually occupied since at least the early 1980s, was seasonal in the early 1960s (Harrison 1961) and dispersed for at least some months after the cyclone in 1986 (Richards 1990a). Other camps that have disappeared may have been replaced by others nearby, e.g., Tully to Scougal Road, Eubenangee Swamp to Russell River. There is evidence that the flying foxes move camp both within and between years, and will camp at levels of aggregation that can vary by several orders of magnitude.

(c) A decline in the area of occupancy may have occurred from Tully to Cardwell but this represents less than 20% of the total area occupied. A decline in the area of habitat has certainly occurred, and is still occurring. Most of the recent 30% decline in the area of lowland vegetation has been within this southern area but most flying foxes were counted in areas where the clearing has been much less. The only alternative source of food is from orchards at which there are greater risks of death. The habitat in the north of the wet tropics and in the McIlwraith and Iron Ranges is relatively unchanged, although the area of lowland forest there is small.

(d) Actual or potential levels of exploitation are high, especially as a result of fruit damage mitigation. Exact numbers killed may never be known but declared figures would suggest mortalities from shooting and fyre fox exceed 2 000 animals, or 1.3%, per year. On islands in the Indian Ocean it is assumed that for a population of flying foxes to be stable, the population has to be at least ten times the number hunted annually (Cheke and Dahl 1981). In this case it would mean that the annual mortality in addition to that which normally occurs would be at least 10 000, presuming there are at least 100 000 adults among the 155 000 flying fox counted. While camp disturbance has been a problem in the past, it is less so under the provisions of the *Nature Conservation Act and Regulations 1994*. Under this act anyone wishing to disturb a camp must obtain a permit if they intend to harm the animals. As an example, some residents of the town of Daintree prevailed upon their council to move a camp they found objectionable, but this was not permitted until nearly all young could fly. Death on electricity supply lines, on roads etc. are unlikely to contribute significantly to overall mortality, although considered a threat to Grey-headed Flying Foxes (Eby 1995).

(e) Parasitic ticks are certainly having an impact in most maternity camps on the Atherton Tableland. However, the majority of the population is little affected and future projections suggest that the ticks will remain a localized problem. In fact, because the IUCN categories are not designed for localized threats to common species, the major maternity colonies at Millaa Millaa could disappear entirely without the species qualifying as Vulnerable. Competition from other flying fox species is unlikely to be a major threat at this stage.

The Spectacled Flying Fox has undoubtedly declined in abundance. There appear to be fewer camps, there is less habitat, they may have declined in range and they are killed at orchards and afflicted by ticks. The question remains, however, whether these trends and threats justify the species to be listed as threatened. The answer is not clear cut.

Arguments for and against listing

The argument in favour of listing

While some of the data may be subjective and the historical data largely lacking, the IUCN criteria states that "the lack of high quality data should not deter attempts at applying the criteria, as methods involving estimation, inference and projection are emphasized to be acceptable throughout" (IUCN 1994, p. 6). Therefore it could be argued that the species should be listed as threatened because it probably meets all necessary criteria. Declines in the population have almost certainly occurred, but the rate of decline is unclear. The consistent testimony of long term residents of the Wet Tropics suggests a dramatic decline, more camps have disappeared than have been found and only 15% of habitat in the lowlands remains. Also an increasing number die in orchards each year as more fyre foxes are erected, and it is possible that the rate of tick paralysis could spread. Any species with a small population would certainly be listed under these conditions and perhaps the Spectacled Flying Fox should be also. It is arguably a weakness of the IUCN Red List Categories that they can fail to invoke protection for declining common taxa until they are no longer a functional part of the ecosystem. Thus the ecological consequences of a 10% decline in a common species may far exceed those of a 90% decline in a rare one. The IUCN categories also fail to give emphasis to taxa, commonly termed keystone species, with multiple links within an ecosystem or between

ecosystems. Usually if the Red List Categories enable conservation to occur at a landscape scale it is a happy accident. Perhaps the Spectacled Flying Fox could be one of these more serendipitous listings, with far reaching benefits for rainforest conservation.

The argument against listing

The primary aim of Red List Categories is to protect taxa that are rapidly moving towards extinction. They have a wide acceptance and level of understanding in the community, because they highlight taxa which are in low numbers or are rarely seen. To maintain the credibility of the Red List Categories in the community, and thus maintain the high level of political support, they should be applied to common species with great caution. Once a species is listed in a threatened category it cannot be shifted to one of lower risk for five years (IUCN 1994). If, after listing, the species does not decline as would be expected from its classification, especially if it is a species that causes economic damage, it will bring the listing into disrepute. If, however, there is unequivocal evidence that a species is continuing to decline rapidly, especially if that evidence can be obtained by members of the community most affected by the species, in this case the fruit growers, then it can be moved to the more threatened category without delay.

There is room for doubt about whether the species deserves listing. As clearing has occurred there have been declines in all taxa that lived in those habitats. The population of the flying fox may be keeping pace with that clearing, relaxing to a new lower level in the habitat that remains, but will persist at a still substantial 15% of former levels. Also the many rarer taxa that have been affected by clearing in the same way should be listed before the widespread Spectacled Flying Fox. The flying fox does face special threats from lethal crop mitigation and, in one part of its range, from ticks, but are these additional sources of mortality greater than the rate of reproduction? We do not know the answer. Before listing an abundant species as threatened, compared to species that are patently uncommon, there is a greater imperative that the community understand and accept the decision without having it imposed upon them. For this reason it might be better to hold off listing until the data on continuing decline are unarguable.

Conservation management

We believe the conservation management of the Spectacled Flying Fox is essential regardless of its status, for two reasons. The first concerns the species' effect on habitat. Most processes occurring in rainforest occur entirely within the vegetation type. Conservation of rainforest therefore involves little more than ensuring that the habitat is kept from major disturbances such as clearing. Spectacled Flying Foxes, however, transcend the rainforest boundary. Therefore the effects, outside the rainforest, of either a decline in flying fox numbers or a shift in their dietary preferences could have major long-term effects on those species of rainforest tree for which the flying foxes are important for pollination or fruit dispersal (Fujita 1987; Richards 1987; Eby 1991; Fujita and Tuttle 1991), and thus on the structure and function of those rainforest types in which those trees occur. They may be particularly important for primary forest species (Banack 1998). These effects may be subtle and may take a long time to be evident (Richards 1991) but nevertheless make the issue of flying fox management pertinent to those charged with rainforest management as well as to wildlife managers and fruit growers. Given the abundance and broad distribution of flying foxes, any effects on their function within the rainforest could be at least as great as those of the cassowary *Casuarius casuarius*, which has a far higher conservation profile. The ecological impacts of flying fox decline should be of concern regardless of the status of the species. For such an abundant species, a decline of as little as 5% in the last three generations still constitutes some thousands of animals. Also a shift in diet from rainforest fruits and flowers to exotic fruits may have effectively removed most remaining flying foxes from rainforest processes.

The second reason is ethical. Flying foxes are intelligent animals, possibly more closely related to primates than smaller bats (Pettigrew and Jamieson 1987). Increasingly society is finding the killing of intelligent animals morally repugnant and demanding humane methods when killing has to occur. Among flying foxes this attitude is reflected by the extraordinary dedication of bat carers who daily rescue paralysed bats and expend vast amounts of money, time and emotional energy caring for flying fox orphans. Just as the community is demanding scientific research be subject to ethical auditing, so it is starting to demand that wildlife control methods are humane. Thus the development of humane methods of crop damage mitigation are essential regardless of their effect on the population of the Spectacled Flying Fox or its conservation category.

These ends could be achieved through the implementation of the following proposals:

- Develop practical and cost effective alternative methods of non-lethal control at orchards.
- Contingent on the success of the above, negotiate phasing out of lethal crop protection techniques.
- Conduct an annual census to ascertain the trends in population of Spectacled Flying Foxes, leading to a population model that considers both the flying fox and those plant species for which it is important for pollination and fruit dispersal.
- Determine the cause of the paralysis tick problem and develop control techniques.
- Implement an education campaign to inform the general community, including farmers, of the important role flying-foxes play in the maintenance of natural ecosystems and to provide a balanced view on the risk of catching viral diseases from flying-foxes.
- Model the characteristics of flying fox camps and plot their distribution in the landscape to test whether camp sites are limiting.
- Negotiate conservation agreements for regularly used camps on private land.
- Model the effects of rainforest clearing on flying fox populations.
- Determine efficacy of the care of orphans and their release to the wild as a technique for conservation management.
- Encourage agroforestry of native trees that combine flying fox food requirements with significant timber producing potential — e.g., Proteaceae, Sapotaceae, Myrtaceae.

In this paper we do not recommend a status for the species. Rather we flag a likely decline in a relatively common species with widespread implications for rainforests, fruit growers and government authorities and leave the reader to decide how it should be classified. The error in the census is such that only a dramatic change in the population will demonstrate a decline but, if anecdotal reports are correct, such a decline is possible.

CONCLUSION

Nelson (1987) suggested that an attempt should be made to locate all flying fox camps in Australia and, on a particular day, count the bats in every camp. This has not been achieved but at least we have attempted something like it for a substantial part of the range of the Spectacled Flying Fox. We have also, through a community, research and industry-based consultative committee, engaged all interested parties in fruitful discussion of relevant flying fox issues. Whether the Spectacled Flying Fox is listed as Vulnerable or otherwise, it is through such discussion that effective conservation management will occur.

ACKNOWLEDGEMENTS

We are most grateful to the many people who helped us find camps and participated in the counts, particularly to the count co-ordinators Stan Breeden, Alexys Chelsea-Eden, Doug and Sandy Clague, Geoff and Sandra Hodgson, Jenny McClean, Dan Murphy, Pam Tully and Nigel Weston. Thanks also to Steve Goosem who provided data on the loss of forest in lowlands, to Gabriel Crowley and Daryn Storch who prepared the figures and to Greg Richards for discussion of his earlier work. Valuable comments on the manuscript were provided by Barry Baker, Chris Clague, Lindsay Delzoppo, Alistair Freeman, Jean Horton, Greg Richards, Bruce Thomson, Mike Trenerry, Jon Womersley and two anonymous referees.

The views expressed are those of the authors and do not necessarily reflect those of the Queensland Parks and Wildlife Service or those of the Queensland Government.

APPENDIX 1

Known Past and Present Colonies.

Cairns (Mulgrave River — Wonga Beach)

Location	Map sheet	AMG E	AMG S	Camp type	Status during census	Land tenure	Threats	Notes
Barron River — Stratford	8064	036320	813480	Satellite	Abandoned	Council		Probably a satellite of Cairns Central Swamp. Area has not been occupied for many years
Cairns Central Swamp	8064	036630	812900	Permanent	Occupied	Council	Habitat destruction, camp disturbance	Moves among several parts of dispersed swamp
Admiralty Island	8064	03700	812900	Satellite	Largely abandoned	Cairns Port Authority	Orchards, habitat destruction	Camp severely culled. Now a few individuals occasionally present
Yorkeys Knob	8064	036345	814055	Satellite	Unoccupied	Council	Habitat destruction, camp disturbance	Small numbers of flying-foxes often camp here intermittently
Green Island	8064	039000	814700	Unknown	Occupied	National Park	None apparent	Resort staff reported 24 flying-foxes on island during census
Fitzroy Island	8064	039300	912800	Infrequent	Unoccupied	National Park	None apparent	Original collection location. Small camp occasionally present
Atherton Tablelands								
Kuranda	8064	035450	813950	Permanent	Occupied	Council	Tick paralysis, orchards	Principal site for release of hand-reared bats
Clohesey River	8064	034425	813725	Seasonal	Unoccupied	Private	Orchards, habitat destruction	Winter to late dry season 1 km up stream from Koah Road Bridge. Not around when Lychees are on so mostly left alone
Mareeba	7963	033340	811930	Permanent/ seasonal	Unoccupied	Council		Banks of Barron River. Camp present for many years until three or four years ago
Powley Road	8063	035645	809450	Seasonal maternity	Occupied	Freehold	Some parts of forest being selectively logged	This camp has been monitored in the past by the School for Field Studies
Wongabel	7963	033990	808665	Seasonal maternity	Unoccupied/ abandoned	Freehold	Orchards, possibly tick paralysis	The first year local residents can recall the camp not occupying area
Tolga Scrub	7963	033825	809410	Seasonal maternity	Occupied	Council	Severely affected by tick paralysis, camp disturbance	Walking track goes through camp. Area shared by Little Red Flying-foxes, which vacated the area only a few nights before the count took place
Topaz	8063	036185	807185	Seasonal maternity	Occupied	Private	Some losses to tick paralysis	Occupied for at least 10 years and has in the past been shared by Little Red Flying-foxes
Zillie Falls	8063	035720	806730	Seasonal maternity	Unoccupied	Council	Severely affected by tick paralysis October to January	Occupied from late October to early February, either migrate to the coast or join the Whiteing Road camp, could be considered a satellite of Whiteing Road
Whiteing Road	8062	03518	805820	Seasonal maternity	Occupied	Private, Council	Severely affected by tick paralysis	A large camp occupied from October to April. There is strong anecdotal evidence that this camp has declined
Brooks Road	8062	035930	806030	Unknown	Abandoned	Private		Little known, may have been vacated at least five years ago

Location	Map sheet	AMG E	AMG S	Camp type	Status during census	Land tenure	Threats	Notes
Mulgrave River — Innisfail								
Fishery Falls	8063	038050	810010	Regular	Occupied	Freehold	Orchards	Located in planted hoop pine
Black Fellows Creek, Edmonton	8063	036800	81880	Unknown	Abandoned	Council		Contained 6 000 individuals before 1983 when moved using 1 700 rounds of bird fright
Bessy Point/ Yarrabah	8064	037380	813050	Unknown	Unoccupied	Council		Intermittent occupation
Deeral Boat Ramp	8063	038500	809600	Regular	Abandoned	Council	Orchards	Camp present for three or four years but has not been seen in last two or three years
Innisfail — Cardwell								
Eubenangee Swamp	8063	039020	807400	Unknown	Unoccupied	National Park	Orchards	Not seen recently. Known to have been present about 15 years ago
Palmerston	8062	037650	805900	Intermittent	Unoccupied	National Park		Anecdotal evidence suggests that this is only used for short periods during migration to the coast in autumn
Banana Island	8162	039850	806170	Satellite	Occupied	Council	Orchards	Formal assessment was not possible but a week before the census there were fewer than 50.
Warrina Lakes	8162	039625	806225	Permanent	Unoccupied	Council	Orchards	Flying-foxes left camp for the first time in many years six weeks before census
Innisfail Dump	8162	039525	806225	Satellite	Largely abandoned	Council	Orchards clearing of camp site camp disturbance	Camp site partially cleared for dump, now return infrequently
East Palmerston	8062	037600	805800	Unknown	Abandoned	Private		Large camp behind banana farm many years ago, rumoured to have been poisoned over six years ago, before flying-foxes were protected
Russell River	8063	038590	807250	Unknown	Occupied	Council	Orchards	Located in swamp land. Unknown before census
South Maria Creek	8162	039820	802710	Unknown	Occupied	Freehold	Orchards	Location not pinpointed as too deep in forest
Paronella Park	8062	038930	804870	Unknown	Abandoned	Freehold		Camp removed many years ago and has not returned
Kurramine Beach	8162	040520	803440	Unknown	Unoccupied	Council	Orchards	Rose Street behind vacant lot, first colonized this year
Castaways	8162	040500	802360	Unknown	Unoccupied	Private	Urban encroachment	Thought to be disturbed by recent subdivision
Frog Hollow	8162	034028	801730	Unknown	Unoccupied	Private		Present eight years ago but absent last year
Schoogal Road	8062	033712	802200	Unknown	Occupation unconfirmed	Private	Orchards	Present for last three to five years but has increased over last two years
Syndicate Road	8062	033841	801125	Regular	Abandoned	Road Reserve		Abandoned approximately four years ago after being smoked out

Appendix 1 — *continued*

Mulgrave River — Innisfail — *continued*

Location	Map sheet	AMG E	AMG S	Camp type	Status during census	Land tenure	Threats	Notes
Rocky Creek	8062	033805	801660	Regular	Abandoned	Freehold		Abandoned three or four years ago
Murray River	8161	033960	800050	Unknown	Unoccupied	National Park	Orchards	Flying-foxes seen emerging from area three to four years ago
Bilyana Road	8061	038120	799730	Regular	Unoccupied	Private	Orchards	Present in December but moved on
Oyster Point	8161	039900	797900	Unknown	Abandoned	Freehold		Camp trees cleared for resort
North Barnard Island	8162	034118	804560	Unknown	Occupied	National Park	Orchards	Small island camp, bats fly ashore to feed
Bedarra Island	8161	034095	800900	Unknown	Unoccupied	Private		Small island camp not seen for two years
Dunk Island	8162	034100	801600	Regular	Unoccupied	National Park	None apparent	None seen for at least a year
Mossman — Cooktown								
Rossville	7966	315800	825520	Unknown	Occupied	private	None evident	
Ayton — Opposite Bloomfield School	7966	032250 032100	823750 823540	Maternity	Occupied Occupied	Private Private	None evident None evident	Two camp sections
Endeavour River	7967			Unknown				Location Uncertain
Oakey Creek/ Annan River	7966	030500	82820	Unknown	Presumed unoccupied	Private	None evident	None seen in vicinity but too inaccessible to reach during census
Newell Beach, Mossman River	7965	32950	81820	Permanent	Occupied		Boat disturbance, orchards	In Mangroves, moves within estuary
Daintree Township	7962	32030	82020	Transient	Occupied	Private/ esplanade	Camp disturbance, orchards	Colony's location shifts regularly often creating satellite colonies. Pressure exists to move the camp when it is within the town. Often temporarily disturbed by boat tours

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